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# Effects of visual expertise on a novel eye-size illusion: Implications for holistic face processing

Genyue Fu [a], Yan Dong [b], Paul C. Quinn [c], Wen S. Xiao [d], Qiandong Wang [e], Guowei Chen [e], Olivier Pascalis [f], Kang Lee [d,e,*]

[a] Department of Psychology, Hangzhou Normal University, China
[b] Department of Psychology, Renmin University of China, China
[c] Department of Psychological and Brain Sciences, University of Delaware, USA
[d] Dr. Eric Jackman Institute of Child Study, University of Toronto, Canada
[e] School of Education, Zhejiang Normal University, China
[f] Université Grenoble Alpes, LPNC, CNRS, France

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ABSTRACT

We examined the effect of visual experience on the magnitude of a novel eye-size illusion: when the size of a face's frame is increased or decreased but eye size is unchanged, observers judge the size of the eyes to be different from that in the original face frame. In the current study, we asked Chinese and Caucasian participants to judge eye size in different pairs of faces and measured the magnitude of the illusion when the faces were own- or other-age (adult vs. infant faces) and when the faces were own- or other-race (Chinese vs. Caucasian faces). We found an other-age effect and an other-race effect with the eye-size illusion: The illusion was more pronounced with own-race and own-age faces than with other-race and other-age faces. These findings taken together suggest that visual experience with faces influences the magnitude of this novel illusion. Extensive experience with certain face categories strengthens the illusion in the context of these categories, but lack of it reduces the magnitude of the illusion. Our results further imply that holistic processing may play an important role in engendering the eye-size illusion.


## 1. Introduction

Rakover (2011) reported a novel "Eye-Size Illusion". This illusion refers to an illusory change in the perception of eye size when the actual size transformations are made only to the size of the face frame, not including the eye area (i.e., the eyes and eyebrows). Specifically, when eyes are embedded in a smaller face frame they are perceived as larger than same-sized eyes embedded in a larger face (Fig. 1). This illusion is similar to the famous Ebbinghaus–Titchener illusion, in which a central circle surrounded by large circles is perceived as being smaller than the same central circle surrounded by small circles (Coren & Girgus, 1978; Robinson, 1998).

Both illusions illustrate a simple size-contrast effect in visual perception, in which a large contextual size makes the target appear smaller, whereas a small contextual size makes the target appear larger. These illusions suggest that our brain cannot ignore the background information when perceiving the target embedded in different contexts. Rakover (2011) further found that the eye-size illusion with human faces was greater than the Headlight-Illusion with cars and the Geometric Form Illusion. Since individuals are more familiar with faces relative to cars and geometric forms, the differential findings with human faces versus cars and geometric shapes suggest that experience may play an important role in the extent to which visual context affects the perception of target size (Rakover, 2011, 2013).

What causes the eye-size illusion is a question that has yet to be answered. One tentative hypothesis is based on the idea that a general visual mechanism is involved in processing this visual illusion with all types of object forms (e.g., faces, cars, geometric forms). By this view, the eye-size illusion would be governed by the same size-contrast effect that applies to other kinds of objects such as the Ebbinghaus–Titchener illusion (Rakover, 2011, 2013). Another hypothesis is that a face specific mechanism might account for the eye-size illusion. Xiao et al. (2014) found that the magnitude of the eye-size illusion was significantly reduced when faces and eyes were inverted, suggesting that a face specific mechanism might account for the occurrence of the illusion more so than a general visual mechanism, given that the Ebbinghaus–Titchener

* Corresponding author at: Dr. Eric Jackman Institute of Child Study, University of Toronto, 45 Walmer Road, Toronto, Ontario M5R 2X2, Canada.
*E-mail address:* kang.lee@utoronto.ca (K. Lee).

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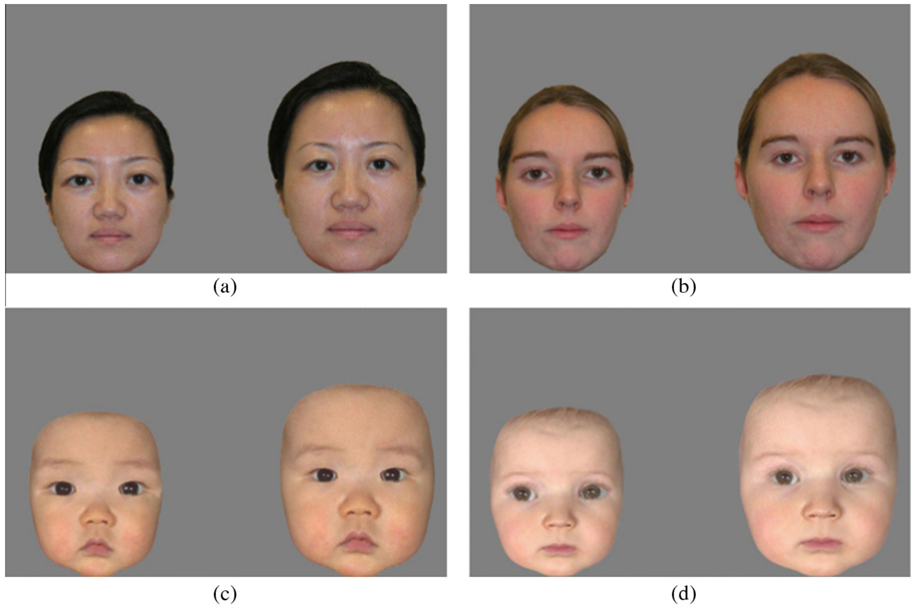

Fig. 1. Examples of a test trial in the Chinese adult face condition (a), Caucasian adult face condition (b), Chinese infant face condition (c), and Caucasian infant face condition (d). The face on the right was the original face, and the face on the left was 14% smaller in the face frame but with the same size of eyes.

illusion is not affected by stimulus orientation (Rakover, 2011, 2013). However, the cognitive mechanism that is impaired as a consequence of face inversion is controversial (Freire, Lee, & Symons, 2000; McKone & Yovel, 2009; Tanaka & Gordon, 2011), which leaves open the question of whether the eye-size illusion is specific to the face processing context. One possible approach to address this question is to examine whether visual experience affects the magnitude of the eye-size illusion. This is because existing evidence suggests that most face processing related perceptual phenomena are strongly affected by visual experience, whereas the Ebbinghaus–Titchener illusion, to the best of our knowledge, is unaffected by observer familiarity with the geometric forms that make up the illusory stimulus.

A prime example of the role of visual experience in face processing is the other-race effect (ORE). The ORE refers to a phenomenon in which individual faces from a non-native racial category are more difficult to discriminate and recognize compared with faces from one's own race (also known as the 'contact hypothesis'; for reviews, see Anzures et al., 2013; Brigham & Malpass, 1985; Hugenberg et al., 2010; Meissner & Brigham, 2001; Sporer, 2001). One of the major mechanisms underlying the other-race effect is that due to the asymmetrical experience with own- versus other-race faces, we are able to process the individuating information of own-race faces better than other-race faces. This information includes the major facial features such as the eyes, nose, and mouth, and the relations between the features which often are referred to as the configural facial information (Lee et al., 2013).

Analogous to the well-documented other-race effect, recent studies also provide evidence for an other-age effect. Adults remember own-age faces more accurately than other-age faces (e.g., Kuefner et al., 2010; Macchi Cassia, 2011; Susilo et al., 2009; for a review, see Rhodes & Anastasi, 2012). In addition, the other-age effect is most robust when the other-age faces are those of infants and the observers are adults without any experience with infants (e.g., Macchi Cassia, 2011). Like the other-race effect, it is generally agreed that familiarity with own-age versus unfamiliarity with other-age faces drive the other-age effect. However, it should be noted that unlike own- and other-race adult faces, own- versus other-age faces (specifically infant faces vs. adult faces) differ not only in terms of internal facial features and configurations, but also in terms of face contour. Indeed, one of the major changes in development from infancy through adulthood is the dramatic transformation of craniofacial shapes. With increased age, children's face contour changes from wide and round to long and narrow (George, Hole, & Scaife, 2000; Lee et al., 2013) in addition to changes in internal face features (e.g., enlargement of eyes, nose, and mouth) and the configurations of these features (e.g., the increase in distance between the eyes and nose and between the nose and mouth: Enlow, 2000).

Because the eye-size illusion is a relatively new perceptual phenomenon, no direct evidence supports the hypothesis that visual experience plays an important role in engendering the eye-size illusion (the visual experience hypothesis). It is entirely unknown whether differential visual experience with different categories of faces (i.e., own-race vs. other-race, own-age vs. other-age) will affect the eye-size illusion differentially. The answer to this question may help point to the mechanism that accounts for the eye-size illusion.

To bridge this important gap in the literature, in the present study, we measured the magnitude of the eye-size illusion for different categories of face stimuli. To measure the threshold of the illusion, we followed the procedure by Xiao et al. (2014). We presented participants an original face pair with the same face with its size either increased or decreased. In the size-altered face, the eye size remained the same but all other face features including the face frame were proportionally increased or decreased. Participants judged which face appeared to have larger eyes. We systematically varied the size change from 14% smaller (i.e., 86% of the original size) to 14% larger (i.e., 114% of the original size). The magnitude of the illusion was indicated by the proportional response of selecting the relatively smaller faces as having larger eyes, given that the actual size of the eyes remained equal throughout (i.e., the higher the proportion, the stronger the illusion).

In Experiment 1, we presented Chinese adult participants with either Chinese or Caucasian faces to examine whether their asymmetrical exposure to own-race Chinese adult faces or other-race Caucasian adult faces would lead to differences in the magnitude of eye-size illusion. In Experiment 2, we presented Chinese adult participants with either Chinese adult faces or Chinese infant faces to examine whether the eye-size illusion would be influenced by the difference in familiarity with adult faces versus infant faces. In Experiment 3, we used the design of Experiments 1 and 2 to examine concurrently the effects of the two factors (race and age) on the magnitude of the eye-size illusion in Chinese and Caucasian adult participants.

Based on the existing albeit indirect evidence, we hypothesized that if visual experience asymmetries with own-race versus other-race faces and own-age versus other-age faces influence the eye-size illusion, the magnitude of the eye-size illusion should be greater for own-race and own-age faces than other-race and other-age faces. Evidence supporting this hypothesis would suggest that experience with the more experienced face types allow the observers to form normalized representations of the face types. Such representations entail a general size constancy whereby the sizes of the face features are normalized proportionally to each other and to the face contour in which the face features reside. Otherwise, if visual experience does not play a role in the eye-size illusion, the illusory magnitude should not differ between the own-race and -age faces and the other-race and -age faces.

## 2. Experiment 1

Here we tested whether the eye-size illusion was affected by asymmetrical visual experience with faces of different categories by comparing the magnitude of the illusion for own-race vs. other-race faces in a group of participants with minimal exposure to other-race faces.

### 2.1. Method

#### 2.1.1. Participants

Nineteen Chinese undergraduate students (7 males, mean age = 19.72 years) participated in the Caucasian face condition, and another 21 Chinese students (8 males, mean age = 20.19 years) participated in the Chinese face condition. Informed consent was obtained and all aspects of this study were performed in a manner consistent with The Code of Ethics of the World Medical Association. All participants reported normal or corrected-to-normal vision. The participants lived in a city with more than 99% of the population being Chinese. None had direct contact with other-race individuals.

#### 2.1.2. Materials and procedure

In the Chinese face condition, stimuli were color photographs of 10 Chinese adults (5 males) in a frontal pose with a neutral facial expression. The faces were shown with a gray background. During each trial, two images of the same individual were displayed on either side of a computer screen, aligned horizontally at the bottom edge. For each face stimulus, we produced 10 variants by changing the size of the original face frame (excluding the eye area) to a different extent (86%, 90%, 94%, 96%, 98%, 102%, 104%, 106%, 110%, 114%).

An initial practice phase trained participants to respond correctly by pressing the key corresponding to the face with the larger eyes. In the main trials, participants were instructed to respond by pressing a key to indicate which face had larger eyes as accurately and rapidly as possible. In the main session, 200 pairs of faces [(10 different original-faces: 5 males and 5 females) × (5 levels of transformation: 2%, 4%, 6%, 10%, and 14%) × (2 directions of transformation: increase and decrease) × (2 positions per pair: left and right)] were randomly displayed on a computer monitor. Another 100 pairs of faces in which the size of the eyes were indeed different were used as fillers to prevent participants from using the

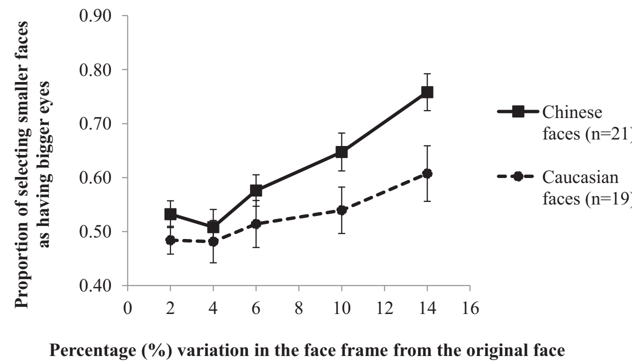


**Fig. 2.** Experiment 1: Mean proportion of smaller face responses as a function of degree of variation in the face frame for Caucasian and Chinese face conditions (Chinese participants). Error bars show ±1 *SEM*.

convenient strategy of picking the smaller faces as having larger eyes. The proportion of participants who selected the smaller face as having larger eyes was the dependent measure.

Stimuli in the Caucasian face condition consisted of 10 Caucasian individuals (5 males) with the same face frame transformations as the Chinese faces. The exact same procedure was followed as in the Chinese face condition.

### 2.2. Results and discussion

We calculated the mean proportion of the "smaller face has bigger eyes" responses in Caucasian and Chinese conditions for each degree of variation. Preliminary analysis revealed that the direction of size manipulation (i.e., smaller vs. larger) did not interact with any of the other variables in Experiments 1 through 3. Hence, data were collapsed across the direction of size change.

The dependent variable (i.e., the smaller face response) was submitted to a 5 (degree of variation: 2%, 4%, 6%, 10%, & 14%) × 2 (race: own vs. other) mixed-model ANOVA with degree of variation as a within-subject variable and race as a between-subject variable to examine the effect of race. The main effect for the degree of variation was significant, $F(4,152) = 25.01$, $p < .001$, $\eta_p^2 = .40$. The main effect of race was marginally significant, $F(1,38) = 3.29$, $p = .077$, $\eta_p^2 = .80$, and the interaction between degree of variation and face race was significant, $F(4,152) = 2.67$, $p = .034$, $\eta_p^2 = .07$. With increasing degree of variation, the magnitude of the eye-size illusion was greater for own-race faces than for other-race faces.

To further explore the race effect, we conducted post hoc *t* tests and found that the smaller face responses were significantly higher for Chinese faces than for Caucasian faces when the degree of variation was 14%, $t(38) = 2.48$, $p = .018$, $d = 0.78$, 95% CI [0.03, 0.27]. These race effects were not significant when the degree of variation was smaller than 14% (Fig. 2). Overall, the illusion became stronger for own-race versus other-race faces when the size of the face frame became larger. This finding supports the hypothesis that differential experience with own-race versus other-race faces affects the magnitude of the eye-size illusion.

## 3. Experiment 2

Experiment 2 examined whether there existed an other-age effect, analogous to the other-race effect, associated with the eye-size illusion. Studies have shown that adult participants not only recognize more familiar adult faces more readily than less familiar other-age faces, but also show a greater composite effect with more familiar aged faces, suggesting that experience plays a critical role in tuning face processing toward specific ages of faces

(Kuefner et al., 2010; Macchi Cassia, 2011; Susilo et al., 2009). Based on these previous findings with the other-age effect, we predicted that the eye-size illusion would be greater for adult faces compared to infant faces in college students, a sample with an arguably greater amount of experience with adult faces than infant faces.

### 3.1. Method

#### 3.1.1. Participants

Twenty-three Chinese undergraduate students (8 males, mean age = 20.30 years) participated in the infant face condition and another 25 Chinese students (6 males, mean age = 20.40 years) participated in the adult face condition. All the participants reported normal or corrected-to-normal vision. Informed consent was obtained and all aspects of this study were performed in a manner consistent with The Code of Ethics of the World Medical Association.

#### 3.1.2. Materials and procedure

Stimuli in the infant face condition consisted of 10 Chinese one-year-olds displaying a full-frontal neutral expression with open eyes. Faces were cropped to be the same size as the adult faces. We performed the same transformations in the face frames as for the adult faces in Experiment 1. In the adult face condition, we used the same set of own-race face stimuli from Experiment 1. Procedure was the same as in Experiment 1.

### 3.2. Results and discussion

The mean proportions of the “smaller face has bigger eyes” responses for infant and adult faces for each degree of variation were submitted to a 5 (degree of variation: 2%, 4%, 6%, 10%, & 14%) × 2 (age: adult vs. infant) mixed-model ANOVA with degree of variation as a within-subject variable and age as a between-subject variable. The main effect for the degree of variation was significant, $F(4,184) = 30.18$, $p < .001$, $\eta_p^2 = .40$. The main effect for face age was marginally significant, $F(1,46) = 4.04$, $p = .050$, $\eta_p^2 = .08$. The interaction between the degree of variation and face age was also significant, $F(4,184) = 5.15$, $p = .001$, $\eta_p^2 = .10$. With increasing degree of variation, the magnitude of the eye-size illusion was greater for own-age faces than for other-race faces.

To further explore the age effect, we conducted post hoc *t* tests and found that smaller face responses were significantly higher for adult faces than for infant faces when the degree of variation was 6%, 10%, and 14%, $t(46) = 2.27$, $p = .028$, $d = 0.57$, 95% CI [0.02, 0.24]; $t(46) = 2.03$, $p = .048$, $d = 0.64$, 95% CI [0.002, 0.27]; $t(46) = 2.66$, $p = .01$, $d = 0.68$, 95% CI [0.05, 0.31]. These age effects were not significant when the degree of variation was smaller than 6% (Fig. 3).

The results suggest that the magnitude of the eye-size illusion is greater for more frequently experienced own-age (i.e., young adult) faces than for less frequently experienced other-age (i.e., infant) faces. These data are in accord with previous results (Kuefner et al., 2010; Macchi Cassia, 2011; Susilo et al., 2009) and together provide support for the idea that the processing underlying the eye-size illusion is better tuned to the type of faces for which participants acquire a greater amount of exposure.

## 4. Experiment 3

Experiment 3 investigated the possibility that face age and race might have an interactive effect on the eye-size illusion. Most research on face recognition has examined the effects of different facial characteristics separately (i.e., sex, age, race). Only a few studies have looked at the combined effects of different facial cues

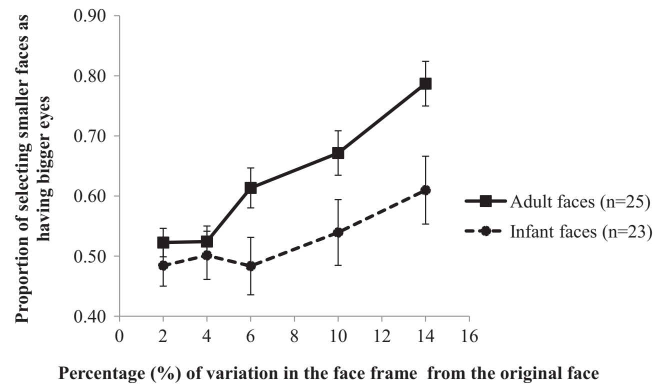


**Fig. 3.** Experiment 2: Mean proportion of smaller face responses as a function of degree of variation in the face frame for infant and adult face conditions (Chinese participants). Error bars show ±1 *SEM*.

(e.g., Macchi Cassia et al., 2014; Quinn et al., 2008; Wallis, Lipp, & Vanman, 2012; Wiese, 2012). For example, Wallis, Lipp, and Vanman (2012) found that face age modulated the other-race effect such that own-race faces were more readily recognized than other-race faces only when the faces were of similar age as the participants. However, other-age faces of different races were recognized equivalently. How face race and age interactively affect the magnitude of the eye-size illusion is unknown. To answer this question, we manipulated both the age and race of face stimuli in the eye-size illusion paradigm and investigated the differences in the magnitude of the illusion across the two facial characteristics.

In addition, in the present experiment, we tested both Chinese and Caucasian adults with the same set of face stimuli to ensure that the results from Experiments 1 and 2 were not due to the specific characteristics of own- and other-race faces used in those experiments.

### 4.1. Method

#### 4.1.1. Participants

A total of 90 Chinese undergraduate students (20 males, mean age = 19.82 years) and 100 Caucasian undergraduate students (17 males, mean age = 21.94 years) participated in this study. All the participants reported normal or corrected-to-normal vision. Informed consent was obtained and all aspects of this study were performed in a manner consistent with The Code of Ethics of the World Medical Association.

#### 4.1.2. Materials and procedure

Participants were randomly assigned to one of the four experimental conditions: Chinese adult face, Chinese infant face, Caucasian adult face, and Caucasian infant face. The Caucasian infant faces were 10 Caucasian 1-year-olds. We performed the same transformation as for the adult faces in Experiment 1. The other stimuli and rest of the procedure were the same as those in Experiments 1 and 2.

### 4.2. Results and discussion

Preliminary analyses showed no significant effects related to participant race. The data were thus combined for this factor in the subsequent analyses. The mean proportions of the “smaller face has bigger eyes” responses in each condition for each degree of variation were calculated (Fig. 4). To examine the effects of age and race on the magnitude of the illusion, we conducted a 5 (degree of variation: 2%, 4%, 6%, 10%, & 14%) × 2 (age: adult vs.

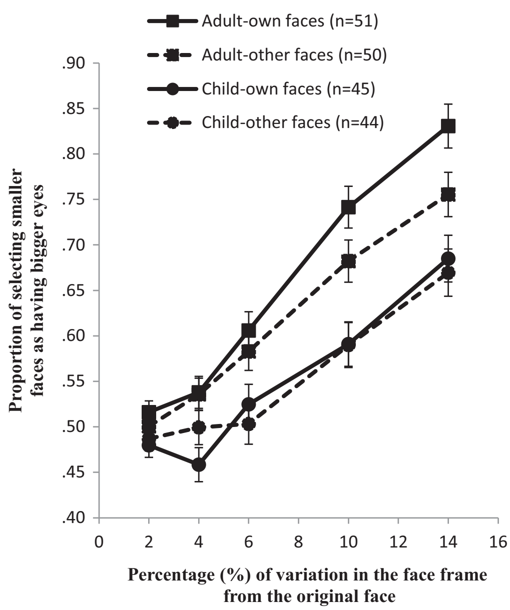


**Fig. 4.** Experiment 3: Mean proportion of smaller face responses as a function of degree of variation in the face frame for own-race adult faces, own-race infant faces, other-race adult faces, and other-race infant faces (Chinese and Caucasian participants). Error bars show ±1 *SEM*.

infant) × 2 (face race: own vs. other) mixed-model ANOVA with degree of variation as a within-subject variable, and age and race as between-subject variables. The main effect for the degree of variation was significant, $F(4,744) = 238.82$, $p < .001$, $\eta_p^2 = .56$. The main effect for face age was significant, $F(1,186) = 22.00$, $p < .001$, $\eta_p^2 = .11$, with the magnitude of the eye-size illusion greater for adult faces than infant faces. The interaction between degree of variation and face age was significant, $F(4,744) = 9.32$, $p < .001$, $\eta_p^2 = .05$. With increasing degree of variation, the magnitude of the eye-size illusion was greater for own-age faces than for other-age faces.

To further explore the age effect, we conducted post hoc *t*-tests and found that participants were more likely to select the smaller face as having bigger eyes when judging adult faces than they did when judging infant faces. The differences were significant when the degree of variation was 4%, 6%, 10%, and 14%, $t(188) = 3.16$, $p = .002$, $d = 0.48$, 95% CI [0.02,0.09]; $t(188) = 3.76$, $p = .000$, $d = 0.53$, 95% CI [0.04,0.12]; $t(188) = 5.09$, $p = .000$, $d = 0.72$, 95% CI [0.07,0.17]; $t(188) = 4.51$, $p = .000$, $d = 0.62$, 95% CI [0.07,0.17].

The interaction between degree of variation and face race was also significant, $F(4,744) = 3.57$, $p < .05$, $\eta_p^2 = .02$. With increasing degree of variation, the magnitude of the eye-size illusion was greater for own-race faces than for other-race faces. To further explore the race effect, we conducted post hoc *t*-tests and found that the smaller face response was marginally higher for own-race than other-race faces when the degree of variation was 14%, $t(188) = 1.79$, $p = .076$, $d = 0.26$, 95% CI [−0.01,0.10]. However, neither the main effect for face race nor the interaction between race and age were significant, $F(1,186) = 0.93$, $p = .34$, $\eta_p^2 = .01$ and $F(1,186) = 1.18$, $p = .28$, $\eta_p^2 = .01$. The three-way interaction was not significant, $F(4,744) = 0.89$, $p = .47$, $\eta_p^2 = .01$. Overall, these results indicate that the other-age effect and other-race effect are independent, and the former is more robust than the latter with respect to the eye-size illusion.

## 5. General discussion

Three experiments were conducted to determine the influence of visual experience on the eye-size illusion. Two major results were obtained. First, we found an other-race effect in the eye-size illusion in Experiment 1: participants observed a greater eye-size illusion for own-race faces than other-race faces. Second, we observed greater magnitude of the eye-size illusion for the more familiar own-age faces than the less familiar other-age faces in Experiment 2. These findings are consistent with the existing evidence that adults are better at recognizing own-age and own-race faces than other-age and other-race faces due to their greater experience with adult faces (for reviews, see Rhodes & Anastasi, 2012 and Anzures et al., 2013). The finding that the magnitude of the eye-size illusion was greater for own-race and own-age faces (i.e., adult faces) than for other-race and other-age faces (i.e., infant faces) supports the hypothesis that visual experience plays a significant role in engendering the illusion.

Further, unlike many prior studies that examined the effects of experience with different facial characteristics on face processing separately, Experiment 3 investigated the possibility of interactive effects of face race and face age on the eye-size illusion. We found only main effects of face race and face age, but no significant interaction between face race and face age. This finding is in contrast to previous observations on the interactive effects between face race and gender on face processing (Quinn et al., 2008; Wallis, Lipp, & Vanman, 2012; Wiese, 2012). For example, Quinn et al. (2008) demonstrated that a visual preference for female faces over male faces in 3-month-olds raised by female Caucasian caregivers was only apparent when the faces were Caucasian, and not when the faces were Asian. Along with the earlier demonstration that infant preference for own-race faces occurs for both male and female faces (Kelly et al., 2005), the findings conjointly suggest that race information supersedes gender information in triggering infant attention (see also O'Toole, Peterson, & Deffenbacher, 1996, for consistent evidence in adults). However, our results generate a different picture regarding the relation between race and age information. That is, age experience was not generalized to other-race faces, and race experience was not generalized to other-age faces. The results taken together suggest that the face attributes of race and age are not represented in the same way as face race and gender in adults.

Although both the other-race face effect and other-age effect on the eye-size illusion were significant, we found a more robust other-age effect than other-race effect in our experiments. The differential magnitude of the effects might be due to the fact that the eye-size illusion relies on the perception of face contour, and marked differences in face contour between infants and adults might play a role in engendering the illusion. It is well established that from birth through to adulthood, the face undergoes significant transformations due to craniofacial growth. Infant face contour is shorter and wider than that in adults, whereas adult face contour is longer and narrower (George, Hole, & Scaife, 2000; Lee et al., 2013). In contrast, despite significant physiognomic differences between faces of different races, the face contours of different races are generally similar (Enlow, 2000). Also, many studies have shown that face contour plays a crucial role in discriminating faces, even in newborns (Ge et al., 2008; Pascalis et al., 1995; Sun et al., 2013; Turati et al., 2006). For example, when the contour of faces is masked, the preference by newborns for mother over stranger faces disappears (Pascalis et al., 1995). Sergent (1984) indicated that the changes in chin contour led to faster reaction times than other features. Moreover, the representation of face contour has been reported to be more important than internal face features for discriminating familiar faces (Young et al., 1985). Overall, our results are consistent with these studies in that face contour is important in processing own- and other-age faces, and may explain why the other-age effect of the eye-size illusion is more robust than the other-race effect of the illusion.

The exact mechanism underlying how visual experience shapes the eye-size illusion needs further exploration. One possibility is that increased experience with own-race and own-age faces may have led to processing expertise for such faces, the hallmark of which is enhanced holistic processing at the individual level (Tanaka & Gordon, 2011). Enhanced holistic processing may have led to increased difficulty for the participants to ignore the face frame when judging the size of the eyes. This holistic processing hypothesis is indirectly supported by research on holistic processing in own- versus other-race face recognition (Michel, Caldara, & Rossion, 2006; Michel et al., 2006; Mondloch et al., 2010; Rhodes et al., 1989; Tanaka, Kiefer, & Bukach, 2004). For example, studies have found that own-race faces are processed more holistically than other-race faces using a face inversion paradigm (e.g., Rhodes et al., 1989), face composite paradigm (Michel et al., 2006), and part-whole paradigm (Leder & Carbon, 2005; Michel, Caldara, & Rossion, 2006; Mondloch et al., 2010; Tanaka, Kiefer, & Bukach, 2004), although the robustness of the holistic processing effect has recently been questioned (Hayward, Crookes, & Rhodes, 2013).

Previous studies have demonstrated that the Ebbinghaus–Titchener illusion, which is similar to the eye-size illusion phenomenologically, may be associated with holistic processing as well. Specifically, the Ebbinghaus–Titchener illusion is affected by the degree to which observers view the stimulus set as an integrated whole as opposed to a collection of unconnected individual components (Coren & Enns, 1993; Pickett, 2001). Autistic individuals, who are argued to have deficits in processing information in context, are less susceptible to the Ebbinghaus–Titchener illusion than normal controls (Happe, 1996). A cross-cultural study reported that people from a remote non-Western culture experience a considerably smaller Ebbinghaus–Titchener illusion than Western controls because they have a local bias in visual processing that is stronger than that observed in Westerners (de Focket et al., 2007). Further, recent studies have revealed that individuals with prosopagnosia show disrupted holistic processing, characterized by an exaggerated local bias and a tendency to focus on specific elements (Avidan, Tanzer, & Behrmann, 2011; Carbon et al., 2007). Taken together, the different data sets provide indirect support for the holistic processing hypothesis. Nevertheless, specifically designed studies are needed to test this intriguing hypothesis directly.

If the holistic processing hypothesis can be further linked with the eye-size illusion, then investigations of the illusion could provide a new phenomenon by which to test holistic face processing specifically in populations to whom the existing paradigms may be difficult to administer. Tanaka and Gordon (2011) have suggested that there exist three empirical paradigms to test holistic face processing: inversion, composite faces, and part-whole recognition. However, although the three paradigms have their own advantages, each has certain limitations. For example, whether inversion indeed disrupts holistic face processing is still highly controversial, and the composite face paradigm and the part-whole paradigm typically have a memory component. In contrast, the eye-size illusion is a perceptual phenomenon. Testing the illusion requires observers to make direct perceptual comparisons between two faces with limited memory load. Thus, the eye-size illusion has the potential to be used as a test for holistic face processing in individuals who have cognitive limitations (e.g., patients with neurological disorders or young children).

It should be noted that the present study has several limitations. First, the faces of only one other-age group were included. It would be important to include older children's faces because adults who are not familiar with infants may have past experience with older children's faces. Whether the eye-size illusion would differ between the faces of adults and those of older children or older adults would allow for ascertaining whether the other-age effect seen here is influenced by here-and-now experience or both past and current experience. The role that face contour plays in generating the illusion could also be probed by these additional age manipulations. Second, throughout the present study, we used between-subject designs to prevent the effects of order from affecting our findings. Future studies may use a within-subject design to establish correlations between the magnitude of the eye-size illusion for own-race and own-age faces and for other-race and other-age faces. Finally, the participant gender distribution in our sample was unbalanced, which made it difficult to test a potential gender effect. Although cross-race and -age studies have so far failed to establish a robust gender effect, existing evidence shows that females may be more sensitive to context in size judgments than males (Phillips, Chapman, & Berry, 2004). Future studies with sufficient male and female participants may be able to assess specifically the role of participant gender in the eye-size illusion.

In conclusion, the current study suggests that visual experience plays an important role in engendering the eye-size illusion: a greater illusion is observed for own-age faces than for other-age faces and for own-race faces rather than for other-race faces. Also, the contour of faces might play an important role in eliciting the illusion as evidenced by the more robust other-age effect than the other-race effect. Furthermore, the differential magnitude of the eye-size illusion with own- versus other-age and race faces suggests that holistic processing may be involved in generating the eye-size illusion (Xiao et al., 2014). We speculate that the eye-size illusion reflects holistic face processing because the eyes are automatically integrated into the processing of the whole face leading to the illusory perception of eye size in the relational context of the whole face.

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